CCL REPORT NO. 205

PROGRESS REPORT

PRELIMINARY INVESTIGATION OF THE TEMPERATURE-FLOW-CORROSION UNIT AS A TOOL FOR COOLANT EVALUATION

BY

JAMES H. CONLEY

JUNE 1966

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PRELIMINARY INVESTIGATION OF THE TEMPERATURE-FLOW-CORROSION UNIT AS A TOOL FOR COOLANT EVALUATION

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U.S. ARMY COATING AND CHEMICAL LABORATORY
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ABSTRACT

The object of this study was to make a preliminary investigation of the Temperature-Flow-Corrosion Unit as a tool for the laboratory testing of automotive coolants.

Nine 500 hour tests were conducted in this preliminary study using antifreeze meeting Federal Specification O-A-548a with and without added inhibitors. Results correlating those received in simulated service and glassware bench tests were obtained in three instances. Mechanical failure and improper functioning of electronic instruments minimized the use of values received in the other six tests.

Results of this study indicate that the Temperature-Flow-Corrosion Unit has the capability of properly evaluating coolants and will serve as a valuable research tool in heat transfer studies.

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I. INTRODUCTION

The Coating and Chemical Laboratory was authorized by AMC Directive, AMCMS Code 5025.11.803 dated 3 September 1965 to conduct research on automotive coolants.

In the past evaluation of coolants involved three phases of qualification: bench corrosion tests, simulated service tests and vehicle field tests. The Temperature-Flow-Corrosion Unit was designed as a single unit which would rapidly produce reliable results correlating with results received in the three phase testing presently practiced. This will reduce the number of expensive and time consuming field tests which are essential to properly evaluate an automotive coolant. The unit may also be used as a research tool in the study of heat transfer and corrosion properties of new and improved coolant formulations.

After installing the unit, a program of study was outlined to evaluate and determine the capabilities, mechanical variables, and test limits of the machine. This report covers the results of the first nine tests conducted.

II. DETAILS OF TEST

A. Apparatus - The Temperature-Flow-Corrosion Unit (Appendix A) consists of a glass-walled test chamber which houses a series of heat accepting metal rod-shaped specimens, such as brass, copper, brass-solder, steel and aluminum. The heat rejecting specimen in this preliminary study was a rod constructed of a special alloy steel with corrosion properties similar to the cast iron used in an automotive engine. Rods of cast iron or aluminum could also be used. The heat rejecting specimen is electrically heated and controlled by a stepless silicon rectifier to maintain a constant metal temperature. The test cell is part of a closed circulating circuit in which the coolant flows through the test cell at a controlled rate, temperature and pressure. The system may also be areated at a controlled rate. The unit is instrumented so that it may be operated 24 hours a day unattended. It has a series of automatic controls which prevent overheating in any way. Relays break the main circuit should the cooling water pressure drop, the specimen overheat, the system leak, or the pump stop.

B. Specimens - The heat accepting specimens are 16" long by 3/16" diameter with a surface area of 60.84 ± 0.5 sq. cm.

The heat rejecting specimen is 12" long by 1/4" diameter with a 1/8" or 1/16" axial hole and a surface area of 95.46 ± 0.5 sq. cm.

C. Procedure - All metal specimens are cleaned and weighed to the nearest 0.1 mg. The specimens are mounted in the test cell and the thermocouples inserted into the heat rejecting specimen at the top and

bottom. Nine liters of coolant are used to fill the unit. The power is turned on, the instruments turned on and the pump started. On this first series of tests the controls were set so that the following conditions recorded:

Solution Temperature	- 180°F. (80°C.)
System Pressure	- 7.6 lbs.
Flow Rate	- 5 G.P.M. (22 cm/sec.)
Aeration	- 0.75 S.C.F.H.

After the solution temperature reaches 180°F. the specimen heat is turned on and gradually increased until a maximum temperature of 257°F. (125°C.) is reached. The heat exchanger valve is partially opened so that the auxillary heater is in operation approximately 30 seconds every minute. Thermocouple readings of solution temperature and heat rejecting specimen temperatures are recorded continuously on an electronic recorder. Periodic readings of these temperatures are taken for calculation of heat flux data. Readings of the voltage and amperage used to maintain the heat rejecting specimen temperature are also taken periodically for the calculation of heat flux data. The test continues for a total of 500 hours.

After the test period the test chamber is opened, the strips removed and scrubbed clean with a soft bristle brush and soap, rinsed with water, then acetone and dried. After they reach equilibrium in a desiccator they are again weighed to the nearest 0.1 mg. and the weight change per sq. cm. is calculated and rated as described in Appendix B Table III.

The test chamber is remounted and the system purged with a mild detergent and rinsed with distilled water.

III. RESULTS OF TEST

Table II shows that corrosion data from tests 2, 5, 6, 7, and 9 correlate with results received in simulated service tests and reported in CCL Report No. 156. Table I shows that in all tests except 4, 6 and 9 there was either a mechanical or electronic malfunction of the unit.

Test no. 4 with 50% 0-A-548a antifreeze and 0-I-490 inhibitor had a fairly uniform heat flux rate of about 26,000 BTU/ft^2 hr and a corrosion rating of 20. This combination in a 2000 hour simulated service test had a rating of 31.

Test no. 6 with 50% 0-A-548a antifreeze and 0-I-490a inhibitor had a gradually increasing heat flux rate from 26,800 to 39,000 BTU/ft^2 hr. and a corrosion rating of 13. This combination in a 2,000 hour simulated service test had a rating of 17.

Test no. 9 with 50% 0-A-548a antifreeze had a fairly steady heat flux rate of 27,600 BTU/ft^2 hr. and a corrosion rating of 37. This combination in a 2,000 hour simulated service test had a rating of 39.

Tests nos. 4, 6. and 9 show the effect of heat rejecting specimen surface conditions on the heat flux rate. Test no. 4 showed that with only slight staining the heat flux rate was fairly uniform. Test no. 6 showed that as the test progressed an irregular coating of iron phosphate was gradually built up and the heat flux rate increased from 26,000 to 39,000 BTU/ft^2 hr. Test no. 9 showed that with a heavy smooth coating build up during the test the heat flux rate increased only 2,000 BTU/ft^2 hr.

In seven of the nine tests the welds on the heat rejecting specimen leaked and had to be repaired. A test apparatus was made to check the welds before they were installed in the test chamber.

All thermocouples were replaced after test no. 3. At room temperature all thermocouples had apparently been recording correctly but at elevated temperatures there were discrepancies. This probably was the reason for the high heat flux rates in tests 1, 2 and 3.

The flow control system was found to be erroneous in tests 5, 7, and 8. In test 3 water from the air line entered the pneumatic valve also in the flow control system.

The flow recorder was repaired twice and the flow controller once in the course of the nine tests.

IV. CONCLUSIONS AND RECOMMENDATIONS

Preliminary data indicates that the Temperature-Flow-Corrosion Unit has the capability of properly evaluating coolants. During these first runs many "bugs" were located which invalidated the results in several of the tests. Difficulties caused by vibration of the unit would be alleviated by mounting all electronic instruments on a separate panel. This would also eliminate heat convection from the heat source into the instruments. The heat rejecting specimen welds should be more solid to eliminate leakage. Unreasonably high heat flux rates in tests 1, 2, 3 and 7 could be explained by malfunction of the flow rate control apparatus. The electronic components of this apparatus have been repaired and recalibrated. All thermocouples needed replacement at some time during these first nine tests. This source of difficulty can only be overcome by close observation and control of the operation.

Research on metal surface conditions and coatings as a means of increasing heat transfer could be conducted with this unit. Mechanisms of the formation of protective coatings which are formed by exposure to

the coolant and the conditions conducive to the formation of these coatings could also be studied. The sample cell can be modified to provide very accurate heat transfer coefficient data of specific systems by the measurement of metal temperature drops with accurately positioned thermocouples.

It is recommended that testing continue on antifreezes which have known physical and chemical properties. Then a definite reliability factor can be assigned to the unit and subsequent research data can be properly evaluated.

V. REFERENCES

1. Authority: AMC Program Directive, AMCMS Code 5025.11.803 dated 3 Sept. 1965.
2. Federal Specification 0-A-548a, Antifreeze, Ethylene Glycol, Inhibited dated 30 Dec. 1958.
3. Federal Specification 0-I-490, Inhibitor, Corrosion, Liquid Cooling System, dated 27 Nov. 1957.
4. Federal Specification 0-I-490a, Inhibitor, Corrosion, Liquid Cooling System, dated 26 April 1965.
5. CCL Report No. 156 - The Development of an Improved Cooling System Corrosion Inhibitor, dated 10 Feb. 1964.

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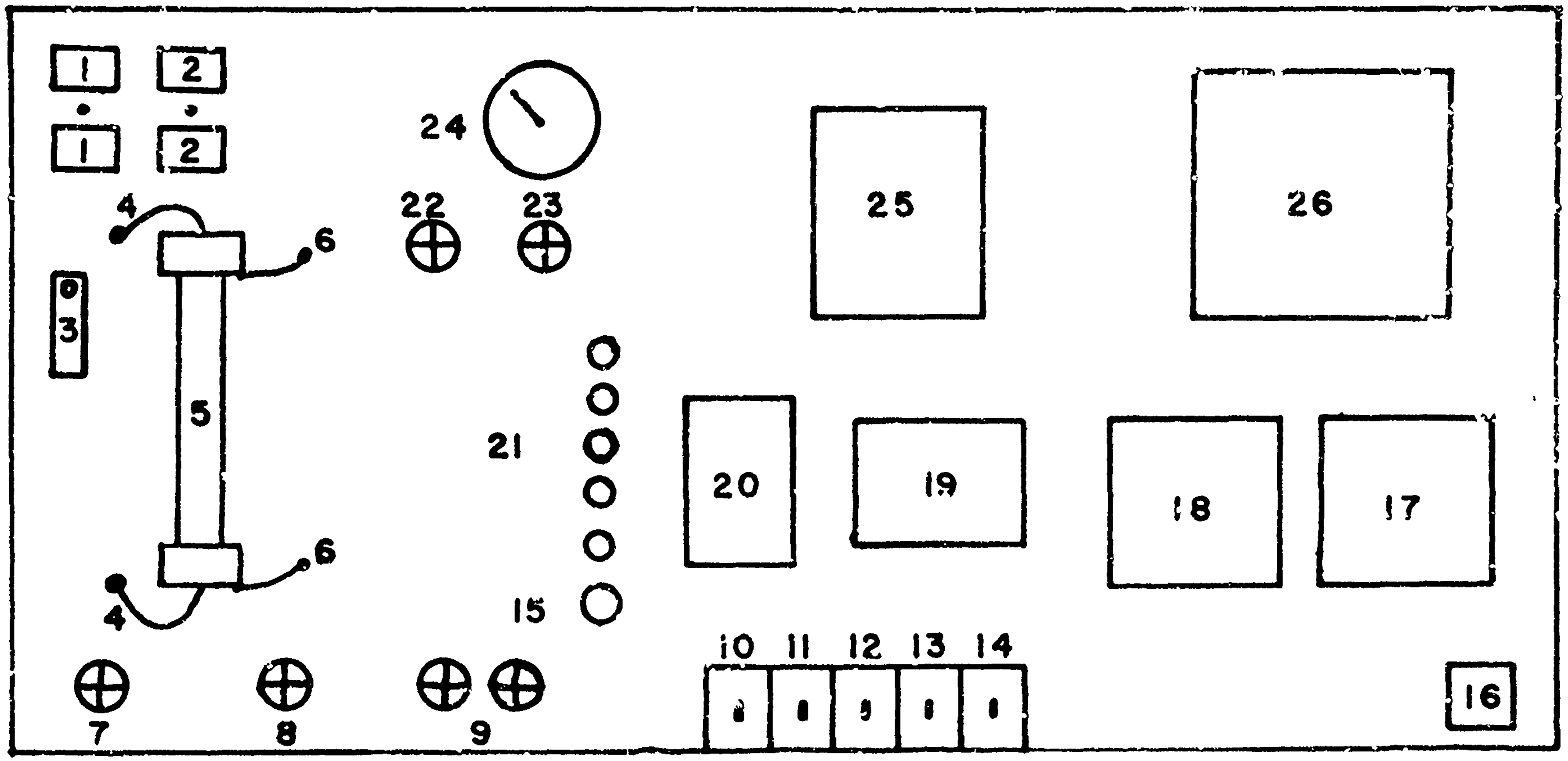

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APPENDIX B

TABLE I

HEAT FLUX DATA

Test No.	Coolant	Hrs. On	Q*	Avg. Metal Surface Temp °F.	Avg. h**	°F Drop at surface of metal	Remarks
1	50% 0-A-548a	2	43,720	223.6°	1552	6.9	75-80% of the avail-
		100	47,600	224.8°	1501	7.5	able power was neces-
		236	52,919	223.4°	1763	8.3	sary to maintain the
		307	50,812	223.3°	1855	8.0	specimen temperature
		404	50,812	223.3°	1777	8.0	
		500	50,812	222.5°	1785	8.0	
2	50% 0-A-548a	19	75,259	244.2°	1155	11.8	90-95% of the avail-
	+	120	74,101	247.4°	1086	11.6	able power was neces-
	0-I-490a	216	75,900	242.8°	1199	11.9	sary to maintain the
		312	79,447	242.7°	1246	12.5	specimen temperature
		384	82,434	242.8°	1286	12.9	
		510	80,311	245.4°	1210	12.6	
3	50% 0-A-548a	4	76,209	244.8°	1161	12.0	Weld on H.R. Steel
	+	89	53,099	239.7°	891	8.3	Specimen Leaking
	0-I-490	201	52,214	237.3°	923	8.2	New Specimen Used
		297	53,190	237.6°	932	8.4	
		400	55,251	237.6°	965	8.7	Water in Air Line
		470	54,713	236.2°	986	8.6	Test Stopped

TABLE I - Cont'd.

HEAT FLUX DATA

Test No.	Coolant	Hrs. On	Q*	Avg. Metal Surface Temp °F.	Avg. h**	°F Drop at surface of metal	Remarks
4	50% 0-A-548a	2	26,282	231.9°	601	4.1	All thermocouples replaced before test started. Weld repaired before test.
	+	97	26,491	232.8°	595	4.2	
	0-I-490	236	25,813	231.4°	603	4.1	
		307	25,291	229.5°	617	4.0	
		405	28,212	235.4°	600	4.4	
		500	26,419	235.1°	571	4.2	
5	50% 0-A-548a	19	22,428	232.5°	513	3.5	Weld repaired before test
	+	98	21,568	231.9°	510	3.4	
	0-I-490a	194	20,838	230.5°	499	3.3	
		315	23,628	234.3°	510	3.7	At end of run flow controller checked and was found to be incorrect.
		428	28,185	232.7°	495	3.6	
		500	23,779	236.1°	475	3.7	
6	50% 0-A-548a	3	26,772	232.9°	596	2.9	Weld repaired before test. Flow set mechanically.
	+	142	27,941	237.5°	537	3.0	
	0-I-490a	200	28,149	237.4°	542	3.1	
		311	31,320	234.9°	634	3.4	
		407	37,572	238.9°	788	4.1	
		502	39,126	232.8°	827	4.2	

TABLE I - Cont'd.

HEAT FLUX DATA

Test No.	Coolant	Hrs. On	Q*	Avg. Metal Surface Temp °F.	Avg. h**	°F Drop at surface of metal	Remarks
7	50% 0-A-548a	93	37,447	241.9°	617	5.9	Weld repaired be-
	+	120	37,448	237.5°	689	6.0	fore test. Flow
	0-I-490	236	50,662	234°	1020	8.0	controller replaced.
		308	61,325	236.4°	1146	9.6	
		427	65,180	235.3°	1235	10.2	Top Solution
		500	66,390	235.1°	1299	10.4	Thermocouple erratic.
8	50% 0-A-548a	Test was stopped after it was discovered that although the flow recorder was reading 5 G.P.M. the flow rate could be changed without any effect at all on the recorder. It was removed and sent to the factory for repairs. This also indicates that the high heat flux rates in Test #7 were also incorrect due to the improper flow readings.					
9	50% 0-A-548a	19	26,032	231.5°	569	2.8	Weld repaired be-
		98	26,669	233.6°	569	2.9	fore test. Flow
		193	27,388	234.8°	565	3.0	recorder replaced.
		306	29,823	235.3°	577	3.2	Extra thermocouple
		411	29,779	234.3°	561	3.0	to top of H.R. spec-
		507	28,222	234.2°	574	3.1	imen installed.

* Q - Heat Flux BTU/ft^2 hr.

** h - Heat transfer coefficient BTU/ft^2 hr °F.

TABLE II

CORROSION DATA

	Weight Changes in mg/cm^2 and Appearance						
Test No.	Aluminum	Copper	Brass-Solder	Brass	Steel	H.R. Steel	CCL Rating
1	-1.00 Light Grey	-0.04 Mod. Stain	+0.02 V.Sl.Stain	-0.02 V.Sl.Stain	+0.01 V.Sl.Stain	-0.46 Very Dark	21
2	-0.20 Black	+0.03 Mod. Stain	-0.21 Brass - Sl. Stain Solder-Pitted	+0.03 Sl. Stain	+0.01 V.Sl.Stain	-0.01 Sl. Stain	15
3	-7.42 Grey	+0.05 Sl. - Mod. Stain	-0.05 Brass - Sl. Stain Solder-Pitted	-0.01 V. Sl. Stain	+0.01 Spot Rusting	+0.03 V.Sl. Stain	20
4	-9.77 Metal torn away at ends Mod.-H. Stain	+0.02 V.Sl.Stain	-0.04 Sl.Stain	+0.02 Sl.Stain	-0.01 V.Sl.Stain	-0.06 Sl.Stain at ends	20
5	-0.33 Black spotted	-0.24 Sl. - Mod. Stain	-0.27 V.Sl.Stain	-0.25 V.Sl.Stain	-0.25 O.K.	+0.16 Tan Coating over 1/2 surface	23
6	-0.11 Black	-0.01 Sl.Stain	+0.04 V.Sl.Stain	+0.04 V.Sl.Stain	+0.07 V.Sl.Stain	+0.50 Iron Phosphate coating over 1/2 surface	13

TABLE II - Cont'd.

CORROSION DATA

Test No.	Weight Changes in mg/cm² and Appearance: Aluminum	Copper	Brass-Solder	Brass	Steel	H.R. Steel	CCL Rating
7	-11.33 Metal Torn away at ends Mod- H Stain	-1.08 H. Stain at ends	-0.61 Brass - H. Stain in center Solder - H. Pitting	-0.36 H. Stain in center	+0.01 Sl. Stain at ends	+0.13 Pitted Light coating	35
9	-2.12 H. Dark Stain	-3.29 Mod. Stain	-2.46 Brass-Black Solder-Pitted ends coated	-2.53 Mod. Stain ends coated	-0.09 V. Sl. Stain Light pitting	+4.39 H. Brittle Green coating	37

TABLE III

STRIP RATINGS

loss mg/cm^2	CCL Rating
.00 - .10	1
.11 - .20	2
.21 - .30	3
.31 - .40	4
.41 - .50	5
.51 - 1.00	6
1.01 - 3.00	7
3.01 - 7.00	8
7.01 - 14.00	9
14.01 - 50.00	10
50.10 +	11

All weight gains have a rating of 1.

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Results of this study indicate that the Temperature-Flow-Corrosion Unit has the capability of properly evaluating coolants and will serve as a valuable research tool in heat transfer studies.

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